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Indian Standard

CODE OF PRACTICE FOR SELECTION AND USE OF FIRE-RESISTANT HYDRAULIC FLUIDS

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *July* 1983

Indian Standard

CODE OF
PRACTICE FOR SELECTION AND USE OF FIRE-RESISTANT HYDRAULIC FLUIDS

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Indian Standard

CODE OF PRACTICE FOR SELECTION AND USE OF FIRE-RESISTANT HYDRAULIC FLUIDS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 April 1983, after the draft finalized by the Lubricants and Related Products Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

0.2 This code of practice has been prepared with a view to recommending basic safety requirements for the selection and use of fire-resistant hydraulic fluids used for various applications, such as mining industry, steel plants, aluminium smelters, die-casting and foundries, plastic processing units, etc. This code prescribes their types, applications and the features governing their selection along with the possible fire hazards associated with the various hydraulic systems.

0.3 In the preparation of this code considerable assistance has been derived from the following publications:

a) Mines Safety Commission of the European Communities. Fifth Report on 'Specification and testing conditions relating to fire-resistant fluids used for power transmission', Luxembourg, 15th November 1974.

b) Association of Hydraulic Equipment Manufacturers. 'Code of practice for the use of fluids in industrial hydraulic system'. London, February 1973.

c) Ralph Lemar 'Proper maintenance practices for fire-resistant hydraulic fluid systems'. Lubrication Engineering, October 1976.

d) IS : 7895-1975 Tests for fire-resistant characteristic of hydraulic fluids used in mining machinery. Indian Standards Institution.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard lays down the code of practice for selection and use of fire-resistant hydraulic fluids used for various applications, such as mining industry, steel plants, aluminium smelters, foundries, die-casting, plastic processing industries, etc.

2. HYDRAULIC FLUID APPLICATIONS

2.1 Fluid power systems are used for mobile applications, such as forklift trucks, mining and earth moving equipment, etc, and stationary applications covering various mechanical actuating and manipulating devices in a wide variety of industries. Particular mention may be made of the mining industry, metal processing units, such as steel plants and aluminium smelters, die-casting and foundries, and plastic processing units where hydraulic systems of diverse designs are employed often to work under hostile environment.

2.1.1 The essential components of a hydraulic system are a prime mover, such as an electric motor or an internal combustion engine, a pumping unit or a torque convertor, an actuator and associated piping and control equipment. Normal fluid pressures in most systems vary from 70 to 280 kg/cm^2 while some special applications may operate at pressures as high as 1 400 kg/cm^2. Apart from its basic function of being an incompressible medium to transmit power, the fluid is expected to possess the following properties:

a) Adequate viscosity at all working temperatures — low enough to ensure easy flowability at low temperatures, and high enough to provide sufficient film strength for lubrication and prevent undue leakage across working clearances at high temperatures;

b) Thermal and oxidation stability at the highest expected operating temperature;

c) Emulsion/chemical stability to give adequate working life;

d) Anti-wear and load carrying capacity;

e) Anti-foam and rapid air-release property;

f) Anti-rust and corrosion-inhibition; and

g) Compatibility with system materials like metals and alloys, elastomer seals and hoses.

3. FIRE HAZARDS ASSOCIATED WITH HYDRAULIC SYSTEMS

3.1 Petroleum fluids are most widely used as hydraulic fluids as they are available in plenty and relatively inexpensive. Besides, these could be readily supplemented with additives to meet the necessary performance requirements. However, petroleum fluids suffer from a serious disadvantage in that they are flammable. Finely dispersed oil droplets in mixture with air could ignite with explosive force under certain circumstances.

3.2 Most mineral oils used in hydraulic systems have flash points between 150°C and 250°C. These fluids when ignited will burn readily and continuously until the oil is consumed. In an ignited high or low pressure spray, the flame can travel both up and down stream. The mineral oil can also ignite spontaneously on contact with a hot surface, and a temperature of about 340°C is often sufficient to cause spontaneous combustion. However, localized temperatures as low as 200°C could also cause eventual spontaneous combustion when the oil is soaked into porous substances like textiles, insulation materials, dust deposits, etc, due to high temperature oxidation reactions.

3.3 Leakage of fluid from pipe connections and gasket fittings, rupture of high pressure pipes and hoses, and accidental disconnection of hydraulic piping under pressure are the common sources of potential danger. At a pressure of even 70 kg/cm^2 the fluid from a pin-hole leak may be projected to a distance of 12 metres. The release of fluid from any of the above causes combined with nearness of an ignition source constitutes a serious fire hazard.

3.4 Ignition sources can be of the following categories:

a) Open flames from gas fired melting crucibles, welding torches and accidental fires;

b) Sparks or arcs from process working, electric welding and short circuits;

c) Hot surfaces of furnaces and furnace parts, lagged pipes, molten metals and frictionally heated parts; and

d) Self-ignition due to overheating of the fluids.

4. TYPES OF FIRE-RESISTANT HYDRAULIC FLUIDS (FRHF)

4.0 Hydraulic fluids used as fire resistant media obtain this property either from the presence of water or from their chemical structure. These fluids, known-under generic name 'fire-resistant hydraulic fluids', are broadly classified under the following categories:

4.1 Classification of FRHF Fluids

Designation	*Class Type*
HF-A	Oil-in-water emulsion usually containing 95 percent water. Combustible material limited to 20 percent *Max.*
HF-B	Water-in-oil emulsions usually containing 40 to 45 percent water. Combustible material limited to 60 percent *Max.*

HF-C	Water-glycol solutions usually containing 40 percent water.
HF-D	Fluids based on phosphate esters, other organic esters or synthesized hydrocarbon fluids containing no water.

4.2 General Applications

4.2.1 *Oil-in-Water Emulsion Types (HF-A)* — These are essentially 2 to 5 percent of soluble oil emulsified in water. These are highly fire-resistant and their chief advantage is low cost. Improved emulsions up to 10 percent oil are used in coal mines for hydraulic roof support systems. The utilization range of temperature for these fluids is 5 to 55°C.

4.2.2 *Water-in-Oil Emulsions (Invert Emulsions) Types (HF-B)* — These are dispersions of water in a continuous phase of mineral oil with the help of special emulsifiers and stabilizers and supplemented with inhibitor and other performance additives. These emulsions normally contain about 40 percent of water. The utilization range of temperatures for these grades is 5 to 60°C.

4.2.3 *Water-Glycols Types (HF-C)* — These are aqueous solutions of poly-glycols containing about 40 percent water. Although these fluids are true solutions and not emulsions, and hence possess better stability, they have other limitations typical of water and oil emulsions besides being more expensive. The utilization range of these fluids is −10 to +60°C.

4.2.4 *Synthetic Fluid Types (HF-D)* — The most commonly used synthetic fluids are phosphate esters, usually mixtures of several single compounds, such a trioctyl, triphenyl, and tricresyl phosphates. These have auto-ignition temperatures in the region of 550 to 600°C and are fire-resistant by virtue of their molecular structure Due to their superior stability characteristics, the utilization range of temperature of these fluids is −20 to +150°C, although the maximum recommended bulk fluid operating temperature is 70°C for large volume systems.

5. FACTORS GOVERNING SELECTION OF FIRE-RESISTANT HYDRAULIC FLUIDS (FRHF)

5.0 The following physico-chemical and performance characteristics have to be considered for the design of the hydraulic equipment as well as for the selection of an appropriate fluid for a given system. These considerations shall also prevail at the time of changing over from one fluid to the other in an existing system.

5.1 Relative Density

5.1.1 Compared to mineral oils, the fire-resistant hydraulic fluids have relative densities as per the following:

Mineral oils	0·87 to 0·90
Invert emulsions	0·92 to 0·95
Water glycols	1·05 to 1·1
Synthetic fluids	1·1 to 1·5

5.1.2 While the higher relative density in the case of invert emulsions is not very sigificant, that of water glycols and synthetic fluids should be taken into account when selecting pumps and designing inlet conditions. Sufficient allowance shall also be made for pressure drop across filters, pipes and couplings. Inlet line filtration shalll be limited to strainers. The adverse effect of high relative density is analogous to that of too high fluid viscosity and could lead to cavitation problems. Cavitation could also be caused by the presence of free water in both emulsions and water glycol mixtures. Flow velocity through suction pipes should not exceed 1·0 m/s and also low or negative pressures at the pump inlet should be avoided.

5.2 Viscosity and V.I. Characteristics

5.2.1 Both water based fluids and synthetic fluids are available in a wide range of viscosities. Emulsion and water glycol mixtures vary in viscosity depending on the amount of water.

5.2.2 With regard to viscosity-temperature characteristics, emulsions and water glycol mixtures have an apparent viscosity index of approximately 150 and there are not normally any problems in relation to the working temperature range. Emulsions, being two-phase fluids, exhibit non-Newtonian behaviour at high shear rates. Under thin film conditions of lubrication, this may result in reduction of equipment life compared to mineral oils.

5.2.3 With regard to synthetic fluids, even when blended with V.I. improvers, they do not compare favourably with conventional mineral oils, particularly at low temperatures. Therefore, careful consideration should be given to the selection of the fluid from the view point of the viscosity-temperature curve in relation to low temperature start-up, as well as the working range of temperatures. In certain low temperature conditions, it may be necessary to make arrangements for heating the fluids for easy cold start-up.

5.3 Stability

5.3.1 The stability characteristics of FRHF differ considerably according to the type of the fluid. In general, the problems pertain to the emulsion break-up in the case of emulsion, loss of water in the case of water glycols, and thermal oxidation and hydrolytic degradation in the case of synthetic fluids. The following are some of the factors that affect the stability of these fluids.

5.3.2 In case of water based fluids, the working temperature range is limited by the water phase. The safe maximum temperature of these fluids is specified as 60°C, since the rate of evaporation becomes high above this temperature. Emulsions are also adversely affected by chemical contamination. The loss of water in the water glycols makes them too viscous, leading to operational problems. Loss of water from both invert emulsions and water glycols decreases their apparent viscosities and reduces their fire-resistance. Hence, a careful check shall be maintained on the water content of the fluids and appropriate replenishment steps should be taken as per the recommendations of the fluid supplier. Normally, loss of water up to about 5 percent could be tolerated. With regard to the low temperature start-up, tank heating should be avoided to the extent possible but, if essential, immersion heater surface should not emit more than 3 W/cm^2.

5.3.3 With regard to the synthetic fluids, although the safe maximum temperature is stipulated as 150°C, the bulk fluid temperature should preferably be limited to 70°C. At higher temperatures, these products are subject to rapid deterioration and therefore need to be checked frequently. If necessary, cooling arrangements for bulk fluids should be adopted. With regard to low temperature start-up problems, the heating capacity of the immersion heaters should be restricted to 0·65 W/cm^2. Although synthetic fluids are not miscible with water, such contamination can lead to corrosion and chemical degradation of the fluids. Therefore, precaution should be taken to avoid moisture/water ingress.

5.4 Lubrication Properties

5.4.1 Oil-in-water emulsions have relatively low viscosity and poor lubricating properties.

5.4.2 Invert emulsions have viscosities similar to, or higher than, normal mineral oil hydraulic fluids; and since the continuous phase is oil, their lubricating properties are usually quite good. They are non-Newtonian fluids, and hence the viscosity can vary depending upon the shear forces applied..

5.4.3 Water glycols are true solutions with excellent viscosity-temperature characteristics. Their lubricating properties are quite good under most hydrodynamic and boundary conditions, but they do greatly reduce the fatigue life of rolling contact bearings.

5.4.4 The 4-ball wear and vane pump tests are used by the industry to evaluate the load carrying and anti-wear properties of these fluids. While no pass limits have yet been laid down with respect to these tests for FRHF, the test data provided by the fluid suppliers and the field experience collated by the equipment manufacturers and users continue to serve as the principal guiding factors in the selection of FRHF.

5.5 Compatibility with System Materials

5.5.1 Hydraulic systems have metallic components made of different types of metals and alloys and a wide variety of elastomers, such as gaskets, seals and hoses. Compatibility between these materials and the fluids should be ascertained before introducing the fluid into the system. The following are some of the considerations in this regard.

5.5.2 Ferrous metals, stainless steel, brass and copper do not generally pose any problem of incompatibility, although galvanic corrosion may occur between copper and steel mating surfaces in water based systems. Most other non-ferrous metals with the exception of magnesium are also compatible with emulsions and synthetic fluids. Difficulties have been known to arise with phosphate esters where aluminium is present as a load bearing surface. Water glycols are compatible with all common metals but zinc, cadmium and magnesium are adversely affected, hence, an adequate system check shall be made for use of water glycols. As a general practice, galvanized piping should be avoided in hydraulic systems using FRHF, as zinc can flake off and introduce contamination. These fluids should not be packed in galvanized drums.

5.5.3 Seals, gaskets and flexible hoses which are compatible with mineral oils are normally satisfactory with emulsions and water glycol fluids. Viton, PTFE, silicone rubber and many other polymers are also satisfactory but the equipment or fluid supplier should be consulted for each application. Cork and leather type materials are unsuitable for water containing fluids.

5.5.4 In the case of synthetic fluids, special care is necessary to ensure compatibility with the elastomers. Materials like Viton, PTFE, silicone and butyl rubbers may be suitable but the fluid suppliers shall be consulted for each application.

5.5.5 The compatibility property is checked by suspending the elastomer material in the fluids for 21 days under given test conditions (temperature 60/150°C). The observations pertain to variation in volume (swelling/shrinkage) and hardening or modification of the elastomer surface.

5.5.6 Paint compatibility is generally poor for all these fluids which attack most paints and release debris that could clog strainers and valves. It is, therefore, desirable to avoid painting of the surfaces that come in contact with fluids, although some fluid suppliers recommend the use of epoxy type paints.

5.6 Filtration

5.6.1 The FRHF, particularly water based fluids, tend to retain contaminant particles, such as dust, pump wear debris, and packing seal materials and do not allow these to settle out as readily as mineral oils do. Efficient filtration is therefore, essential for ensuring adequate protection to the equipment. The following are some general guidelines in this regard.

5.6.2 On the pump inlet side strainers which can remove discrete particulate matter should be used. These should have their flow capacity minimum twice or preferably 4 times the rated pump capacity, so as not to aggravate suction lift conditions. Filters in the high pressure circuit and tank return lines should be able to remove contaminant particles in the range of 10 to 25 microns. These filters also should possess flow capacity preferably 4 times that of the pump rated capacity. Filter materials shall not react with the fluids to cause removal of additives.

5.6.3 The inlet strainers are generally metal wire-mesh or of sintered type. Earth filters and felt type elements are not recommended, particularly for water based fluids. If paper filters are to be used, these should be of resin-impregnated type.

5.7 Toxicity

5.7.1 FRHF specifications in most developed countries have stringent toxicological criteria. These pertain to determination of acute toxicity, irritation of skin and mucous membranes based on laboratory investigations on animals. Due consideration is required in this regard for adoption of suitable methods for evaluating products used in the country.

5.8 Fire-Resistant Properties

5.8.1 Fire-resistant properties are the primary requisite of FRHF. The Indian Standards Institution, after considerable review of the various international standards and practices in this regard, has formulated IS : 7895-1975* which prescribes the following three tests for fire-resistant characteristics of hydraulic fluids used in mining machinery:

a) *Autogenous ignition temperature test* — The fluids are expected to have auto-ignition temperatures of not less than 315°C;

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*Tests for fire-resistant characteristics of hydraulic fluids used in mining machinery.

b) *Temperature-pressure spray ignition test* — The flammability chaaracteristics of the fluids are limited under certain defined conditions of fluid spray over three different ignition sources; and

c) *Flame propagation in a mixture of fluid and coal dust* — A mixture of 75 g of specified coal dust and 37·5 ml of the fluid is expected to restrain propagation of flame to certain defined limits under the condition of the test.

5.8.2 The Director General of Mines Safety of the Government of India has been designated as the approving authority for qualifying hydraulic fluids as fire-resistant. The Indian Institute of Petroleum, Dehra Dun, and the Central Mining Research Station, Dhanbad, are expected to provide the necessary testing and evaluation facilities and assist the Director General of Mines Safety in his approval function.

5.9 Change-Over from One Fluid to Another

5.9.1 As most hydraulic systems are designed to operate on mineral oils, the first important step is the selection of an appropriate fluid based on considerations of system design and operating conditions, with particular reference to type of pump, system materials and elastomers, and anticipated range of operating temperatures. For introducting the selected fluid in the system, particularly when a different fluid is already in use, the following procedure is suggested:

a) The hydraulic system should be drained as completely as possible, paying particular attention to the low level points in pipelines, pumps, valves and other accessories. If possible, some of these components should be dismantled and cleaned;

b) All filters should be cleaned and replaced. Paper filter elements should be renewed, paying attention to the need for the resin-impregnated type;

c) Seals, hoses and other elastomer materials should be checked and replaced as per compatibility requirements;

d) The system is given an initial fill of the fluid for purpose of flushing. In the case of water based fluids, the system if run under no-load condition for about two hours or as per the duration suggested by the fluid supplier. In the case of synthetic fluids, the system is operated for a period of 16 to 24 hours; and

e) The flush charge is drained while the fluid is warm, again paying attention to the low level points. The system is then given a fresh charge and is ready for operation.

5.9.2 For ensuring a proper quality leval of the fluid at first fill and also during use, the following additional control checks would be of help:

a) In the case of emulsions, water content and droplet size of water particles are of importance. Stable invert emulsions could be prepared only through vigorous agitation using equipment, such as high speed stirrers, homogenisers and sonic vibrator emulsifiers. The average water particle size should be controlled at a 2-microns level, with only a few random particles of 4 to 5 microns;

b) Water content should be checked in the case of both emulsions and water glycols, either through direct determination of water or indirectly from viscosity and density considerations. For make-up of water which should invariably be distilled or deionized, the fluid supplier should be consulted on the methodology;

c) In the case of water glycols, acidity tests also help detect contamination or component depletion. A change in *p*H value of more than 0·5 should alert the user for more detailed investigation for contamination or component depletion.

d) Synthetic fluids could be checked for contamination, through periodic routine determinations, such as density, water content, acidity and settling tests. It is however desirable that the fluid supplier should be consulted on more precise methodology of exercising quality checks on the product in use. Mineral oil contamination should be restricted to 5 percent, *Max*.

(*Continued from page* 2)

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2